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ALTERNATIVE EQUIPMENT FOR THE INCINERATION OF NONCONDENSIBLE GASES

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Introduction

In the course of the chemical pulping process, malodorous gases are formed in the digester. These noncondensible gases (NCG) can vent from various process vessels and escape to the atmosphere. Regulations restricting the discharge of these gases continue to be enacted. As mills make their plans for the collection and incineration of NCG, one of the key decisions that has to be made is the determination of where the gases are to be incinerated. This paper is intended to review the various options for incineration of NCG, and discuss the considerations in selecting the incineration method. Advantages, disadvantages, and limitations of each incineration method will be included, as well as safety, process, and cost considerations.

Characteristics of Kraft Pulp Mill Gases

Pulp mill noncondensible gas (NCG) can be generally divided into three categories. One category includes the low-volume high-concentration (LVHC) gases, often referred to as strong gas. Examples of the sources of this type of NCG are:

- Turpentine Recovery
- Blow Heat Recovery
- Evaporator Hotwell / Aftercondenser
- Foul Condensate Storage Tanks
- Continuous Digester Relief
- Steam Condensate Stripping

Another category of NCG includes the high-volume low-concentration (HVLC) gases, often referred to as dilute gas. Examples of the sources of this type of NCG are:

Weak Black Liquor Storage Tanks

Knotter (Screen) Hoods

Brown Stock Washer Hoods

Brown Stock Washer Filtrate Tanks

Brown Stock Washer Intermediate Stock Chests

Brown Stock Washer Foam Tanks

Oxygen Delignification Blow Tanks

Oxygen Delignification Post O_2 Washers

Oxygen Delignification Filtrate Tanks

Oxygen Delignification Interstage Pulp Storage Tanks

Decker Hoods and Filtrate Tanks

Chip Bin Relief Condensers*

Air Condensate Stripping*

** Special consideration must be given to these sources for its potential for containing significantly higher quantities of turpentine vapor and sulfides.*

Environmental regulations over the last 15 to 20 years have typically required that only the SOG and LVHC gases be collected and incinerated. However, with the enactment of more restrictive regulations pertaining to the control of pulp mill emissions, both new mills and some mills with major expansions will be required to collect and control the HVLC gases in many countries.

The flow rates and compositions of the NCG vary with the source process design, the condition of the source equipment, and the wood being pulped. For this reason, the NCG sources must be carefully studied prior to design.

In general, the HVLC NCG from kraft pulp mills can be characterized as wet air, contaminated with TRS compounds (e.g. hydrogen sulfide, methyl mercaptan, dimethyl sulfide, and dimethyl disulfide) methanol vapor, and, in some cases, turpentine vapor as well as other organic compounds. The concentration of these contaminants is typically below the lower flammable limit (LFL) for the actual mixtures of these compounds with air. The exact value of the mixture's LFL will depend on the relative amounts of the various contaminants, and will typically lie somewhere in the range of two to five (2-5) volume percent. Maintaining the concentration of these gases below the LFL is of significant value to the safety of the system, since gases with concentrations below the LFL will not sustain combustion without additional fuel.

The LVHC NCG from kraft pulp mills, on the other hand, consists of high concentrations of TRS compounds and methanol vapor, with insufficient oxygen to sustain combustion. It is desirable to maintain the concentration of the combustibles above the upper flammable limit (UFL), in order to preserve the LVHC gas stream in this inherently safe state. As with the LFL, the exact value of the UFL will depend on the relative amounts of the various combustible compounds present in the gas mixture, although it is typically expected to lie somewhere in the range of 20 to 40 volume percent.

A special category of LVHC gas is overhead vapor from a foul condensate steam stripping system. This vapor is a mixture of methanol, water, and total reduced sulfur (TRS) compounds, and is usually referred to as Stripper Off Gas (SOG). Because of its special composition and properties, it is handled separately from the other LVHC gases. It is important to note that SOG is, unlike other pulp mill waste gases, a condensible gas. Therefore, if it is to be burned as a gas, it must be transported in insulated pipe lines, and must not be cooled or combined with either LVHC or HVLC NCG.

Incineration Options For Noncondensible Gases

A number of options are available for the incineration of the NCG in a kraft pulp mill. These options include a recovery boiler, a power boiler, a dedicated waste gas incinerator, a lime kiln, and a regenerative thermal oxidizer (RTO). The viability of each of these options depends on site-specific considerations, which include the following:

- The volume of the NCG to be incinerated.
- The air flow requirements, relative to the NCG flow, for the incineration point under consideration.
- The regulatory permit requirements for the incineration point under consideration.
- The existence of stack monitoring equipment for SO2 and/or TRS on the incineration point under consideration.
- The existence of flue gas scrubbing equipment for SO2 on the incineration point under consideration.
- The cost of oil or natural gas to be used as either primary or auxiliary fuel for a dedicated waste gas incineration system.
- The availability of high-Btu-value waste gas (especially SOG) to provide the primary fuel for a dedicated waste gas incinerator.
- The physical proximity of the various candidate incineration points to the majority of the NCG sources.
- The availability of a suitable location for the injection of NCG gases into the incineration point under consideration.
- Past experience with the incineration of waste gases in one or more of the candidate incineration points.
- The operational availability factor for each of the candidate incineration points.
- The potential for corrosion in existing air systems and/or leakage of malodorous and noxious gases to the surrounding mill environment.
- The presence of turpentine vapors in the NCG.

Comparison of Various Incineration Options

A comparison of the various options for NCG incineration should take into account the considerations listed above for the specific site. Several typical guidelines can be used to facilitate this evaluation.

1. NCG Flow Rates and Incineration Point Air Flow Requirements

The volume of the HVLC NCG to be incinerated is typically on the order of 10,000 to 40,000 actual cubic meters per hour, or even more, depending on the types of sources being collected and the age and condition of the source equipment. This flow rate is on the order of magnitude of the total forced draft air flow requirement for most lime kilns and many smaller power boilers, and in many cases may even exceed that requirement. For this reason, HVLC NCG is not typically burned in lime kilns, unless the HVLC NCG system is dedicated to only one or a few sources. On the other hand, larger boilers, including recovery boilers, may have forced air flow requirements that are five or ten times the flow of the HVLC NCG, and they are therefore a much better "fit" for the incineration of these gases. A dedicated waste gas incinerator or a RTO can be sized to handle even the highest HVLC NCG flows.

The volume of the LVHC NCG to be incinerated is typically on the order of 500 to 2,000 actual cubic meters per hour, again depending on the types of sources being collected and the age and condition of the source equipment. This volume of gas can be handled by most existing lime kilns and power boilers. It must be noted, however, that the LVHC gas (and especially SOG) has a net positive fuel value, and will, therefore, increase the demand for combustion air within this type of existing equipment.

2. Regulatory Permit Requirements

The regulatory permitting requirements for fired equipment with stack emissions often varies from region to region and even from mill site to mill site. In some situations, the permit granted to existing equipment may allow the incineration of NCG without a re-permitting process. When this is the case, it would favor the utilization of existing equipment for burning the NCG over new dedicated equipment (such as an incinerator or a RTO), which would require an entirely new permit.

3. Stack Monitoring Requirements

Many existing power boilers that use low-sulfur fuels do not have continuous emission monitoring systems (CEMS) for their flue gases. The recovery boiler, on the other hand, normally burns concentrated black liquor, which contains sulfur compounds including TRS. For this reason, the recovery boiler, which normally captures most sulfur compounds in the smelt as useable product, typically has a CEMS to monitor TRS. It may also have a CEMS for S02 as well.

This may favor the recovery boiler over some power boilers for burning of NCG, since it may eliminate the need for additional stack monitoring systems. However, it is not an advantage when comparing the recovery boiler to dedicated waste gas incineration systems, which typically provide effective incineration and flue gas scrubbing through the demonstrated control of furnace temperature and residence time, scrubbing media pH, and scrubbing media flow, without the requirement of an installed CEMS.

4. SO_2 Scrubbing Requirements

Many existing power boilers that use low-sulfur fuels do not have flue gas scrubbing equipment for the removal of SO_2 emissions. The recovery boiler, which oxidizes certain sulfur compounds contained in the black liquor to SO_2, typically does not require such equipment due to the subsequent buffering reactions in the recovery boiler. The burning of NCG in the recovery boiler usually does not increase the generation of SO_2 in the boiler furnace to the degree that the allowable level of SO, for the boiler's stack emissions permit will be exceeded. This is because the mass of sulfur as TRS compounds in the NCG is very small in comparison with those sulfur compounds in the black liquor that will oxidize to SO_2. This characteristic of the recovery boiler eliminates the need for additional SO, scrubbing equipment which might be required for NCG in a power boiler, in a waste gas incinerator, or in a RTO.

5. Fuel Requirements and Availability of High Fuel Value Waste Gas

Since LVHC NCG has a net positive fuel value, little or no additional auxiliary fuel for its incineration is required.

Since the HVLC NCG simply replaces part of the forced draft air that is required by the recovery boiler, the additional fuel consumption required by dedicated incineration equipment, such as a waste gas incinerator or a RTO, is avoided. In comparison to a waste gas incinerator, this advantage may be only slight, if a high-Btu-value waste gas stream, such as SOG, is available for combustion in the incinerator. Those mills with properly designed and operated foul condensate steam strippers will have a methanol-rich off-gas stream that can be used to drastically reduce the consumption of auxiliary fuel, such as oil or natural gas, in the incinerator. The use of SOG as a fuel source for a RTO raises concerns, due to possible difficulties in temperature control of the RTO packed beds.

If the flow of HVLC NCG is very high, then it is quite likely that the SOG fuel source will be insufficient for the operation of a dedicated incinerator. In this situation, it is necessary to compare the fuel requirements to the available waste gas fuel, before a decision with respect to an incineration point can be made.

6. Physical Layout and Proximity to Waste Gas Sources

Dedicated incineration systems, such as an incinerator or a RTO, may be located much closer to the majority of the NCG sources. This could produce a savings in the installed cost of the NCG system that would partially offset the cost of the new incinerator or new RTO. Furthermore, by reducing the length of the collection header, it is possible to reduce the horsepower requirements for the HVLC NCG collection fan and the motive steam requirements for the LVHC NCG ejector. The physical layout of the plant will always be an important consideration.

7. Space Requirements

Since the HVLC NCG flow rates are typically quite high, and the resulting HVLC NCG pipelines to the incineration point are often quite large (on the order of 600 mm to 900 mm), a suitable location that is physically accessible for the injection of the HVLC NCG into the incineration point must be identified before the final decision on the incineration point can be made. It is typically good practice to inject the HVLC gases into the tubular air heater inlet or outlet for some power boiler designs, and into a secondary air duct downstream of the air preheater for the recovery boiler. The individual boiler design must be studied with respect to good mixing of the HVLC NCG with the balance of the boiler air, the avoidance of low points where TRS compounds and/or turpentine-laden condensates could accumulate. The availability of sufficient space for HVLC NCG pipe routing and the HVLC NCG system equipment installation must also be considered.

Due to the relatively low flow rate of LVHC NCG and SOG, and their correspondingly small pipelines to the incineration point (typically 100 mm to 200 mm), it is usually relatively easy to find a suitable location that is physically accessible for the injection of these gases into most incineration points. If the incineration point is a power boiler or a recovery boiler, then it is typically good practice to inject the gases directly into the boiler furnace. These gases should not be mixed with the boiler air in the way described above for the HVLC NCG.

8. Past Experience with the Incineration of Waste Gas

In some cases, a given mill site will already have successful experience with the incineration of waste gases in a particular incineration point. Other considerations being equal or nearly so, this experience of the mill's operations, maintenance, and engineering staff may provide a valid justification for selection of a similar incineration point for the burning of the additional NCG.

9. Availability Factors

Generally speaking, recovery boilers have high availability factors and, if the recovery boiler is not in service, then the remainder of the mill will also shut down within a short period of time. This is an advantage over lime kilns, which are subject to more frequent interruptions in operation. Recovery boiler operations tend to be steady, unlike some power boilers whose rate of firing may fluctuate somewhat with steam demand. These relative advantages, however, are not enjoyed over dedicated waste gas incinerators, which are known to achieve steady operation and 98% availability.

10.Corrosion and Leakage of NCG in Existing Air Systems

The introduction of HVLC NCG into the air supply systems of either recovery boilers or power boilers often raises the concern of potential corrosion in the existing air ductwork or windboxes. It can also raise concerns regarding the leakage of malodorous and noxious gases from corroded ductwork and leaky joints into the surrounding mill environment. These concerns can be effectively addressed by ensuring that the gases are both dry and superheated before their introduction into the boiler air system, and by verifying and maintaining the mechanical integrity of the air ductwork and its joint gasketing or sealant. Another approach for"dealing with these concerns is to inject the HVLC NCG directly into the boiler furnace, similar to the waste gas injection that is generally done for dedicated waste gas incinerators and lime kilns (and for LVHC NCG in boilers as well). One disadvantage to this approach is the investment required for a sizable boiler tube wall modification. Another disadvantage is that the beneficial dilution, obtained by combining the HVLC NCG with other boiler air, is lost when the HVLC NCG is injected directly into the furnace.

11.Turpentine Vapor from Special Sources

The potential for high levels of turpentine vapors in the NCG of softwood mills can raise safety concerns due to that vapor's high flame propagation speed and low flammable limit (less than one percent) in HVLC NCG. In a fundamental sense, the need to eliminate high concentrations of turpentine vapor in the NCG is a safety requirement regardless of which incineration option is selected. In a practical sense, however, the size of the HVLC NCG system and the actual location of each viable incineration option may affect the determination of how to deal most effectively with HVLC NCG from sources that present a potential for high turpentine concentrations (for example, chip bins and air stripping systems). In a smaller HVLC NCG system, the chip bin gas would not be diluted so much when combined with gases from the other sources. It might be advisable under such circumstances to collect and incinerate the chip bin gas separately from the other HVLC NCG. In this case, it is quite conceivable that the chip bin gas might be burned in one incineration point (close to the chip bin), while the other HVLC NCG might be burned in another incineration point (located more conveniently with respect to the rest of the HVLC NCG sources).

Safety and Operational Considerations

In order to obtain the safe and reliable incineration of the NCG in any incineration point, a number of safety and operational considerations are necessary. In the case of recovery boiler incineration, special consideration is given to the elimination of moisture from all waste gas streams and the introduction of HVLC NCG to the incineration point as a superheated gas without any entrained liquids. This minimizes any concern that the HVLC NCG system could become a source of corrosion in existing air supply systems or of liquid coming into contact with the smelt bed in the boiler.

The following list is intended to provide the reader with generic system design guidelines. However, any actual NCG incineration system will require individualized and detailed scrutiny, and possible additions to this list. In particular, careful planning of the NCG gas pipeline routing must be done to ensure proper sloping of the lines, as well as the elimination of low points in the piping (or the proper drainage of low points when these are unavoidable).

1. As described above in the section "Characteristics of Kraft Pulp Mill Gases," the HVLC NCG sources are those whose combustibles concentrations can be maintained consistently below the LFL. Therefore, the collection of strong (LVHC NCG) sources into the HVLC NCG system must be avoided, since the inclusion of even one strong source creates the potential for pushing the combustibles concentration of the combined HVLC NCG gases above the LFL.
2. The gas lines must be sized to provide safe line velocities above the flame propagation speeds of methanol and TRS compounds. This is especially important for the gas line going to the incineration point. A low gas flow interlock must be provided for this line to ensure that the gases are vented if this safe line velocity is not maintained.
3. For HVLC systems, ambient flow make-up air must be provided on flow control both to ensure a minimum safe line velocity and to maintain a steady flow of gas to the incineration point. This allows the HVLC NCG system to provide a consistent contribution of air to the incineration point, even when the system experiences variation in gas flows from one or more of the sources.
4. Flame arresters provided in the gas lines at every LVHC NCG source and just upstream of where the NCG is injected into the incineration equipment will protect the LVHC sources and the NCG system equipment from damage in the unlikely event of a source of ignition combined with a gas combustibles concentration above the LFL and below the UFL. A temperature transmitter, located between the flame arrester and the gas injection point, provides a high temperature interlock which will cause the NCG system to vent its gases to atmosphere in the unlikely event that burning were to occur at this point.
5. Entrainment separators are included in the NCG system both to serve as low point drains and to eliminate liquid droplets entrained in the gas stream. The condensate collection tanks for the entrainment separators as well as any other low point drains are monitored with level switches or transmitters. This instrumentation provides high level interlocks which vent the NCG system gases whenever the liquids are not removed properly. These provisions are especially important for incineration of the NCG in the recovery boiler, since the introduction of liquids to the boiler furnace must be strictly avoided.

6. A gas heater is included in the HVLC NCG system to superheat the gas before it is injected into the forced draft air stream going to either the power boiler or the recovery boiler. This accomplishes the same preheating that is required for the forced draft air for which the HVLC NCG is substituted. It also ensures that the HVLC NCG is free of liquid moisture, by preheating the gas to a temperature well above the dewpoint. In addition to addressing the safety of the installation, the preheating prevents the corrosion that would otherwise occur, particularly in the boiler's air supply system. The gas heater may be of either shell-and-tube or steam-coil design. A low temperature interlock for the HVLC NCG at the point of injection into the boiler will vent the HVLC NCG until a minimum gas heater outlet temperature is obtained. The HVLC NCG system vent at the boiler is located downstream of the gas heater. This allows the gas temperature to be re-established while venting the HVLC NCG.

7. A rupture disc, provided in the gas lines at every LVHC NCG source and near the NCG incineration points, will protect the LVHC sources and the NCG system equipment from damage in the unlikely event of high pressure due to a fire in the NCG lines. The system also includes a pressure switch located near each rupture disc with an interlocked high pressure alarm that will vent the NCG whenever the gas line pressure near the rupture disc approaches the burst pressure of the disc.

8. A combustibility meter, used to detect the percent of LFL in the HVLC NCG can be used to alarm at a given concentration, or can even provide an interlock that vents the system when the combustibles concentration in the HVLC NCG becomes too high. In order for such an interlock to be effective, it is necessary to install the meter(s) near the source or sources which may be expected to experience high combustibles concentrations, and then vent the combined system HVLC NCG near the incineration point on high percent LFL.

   These meters have been used successfully at a number of mills. They do require regular calibration and maintenance in order to obtain reliable results and to avoid nuisance trips. Assuming that they receive the appropriate attention, they can be a useful safeguard. However, they should not be used as substitutes for a design that eliminates high concentrations of combustibles in the HVLC NCG. In a properly designed HVLC NCG system, which incorporates the other safety considerations mentioned herein, combustibility meters can be omitted while still maintaining safe HVLC NCG collection and incineration.

9. Chip bin vents present the potential for high concentrations of combustibles, including (in softwood mills) turpentine vapors. While it is true that the chip bin's NCG combustibles are diluted significantly when combined with gas from other HVLC NCG sources, additional system safeguards are necessary in order to avoid combustibles concentrations in excess of the LFL in the combined HVLC NCG going to the incineration point. It is therefore important that the operation of the chip bin, as well as the handling of its vent gas, be designed to eliminate high combustible concentrations due to vapor "blow-throughs" or other chip bin upsets. This will require stable operational levels and temperatures in the chip bin, an adequately-sized chip bin relief condenser, and an interlock that vents the chip bin source to the atmosphere on high temperature at the chip bin relief condenser vent.

   The design of the chip bin itself, as well as the control strategy for the pre-steaming of chips in the bin, will also affect the determination of safeguards that are required to maintain low concentrations of combustibles in the bin's vent gas.

10. The following list is a summary of the typical interlocked permissives that must be satisfied in order to burn NCG.

- Incineration equipment ready to receive NCG. (This is typically a combination of several conditions; for example, a certain minimum steam production (in boilers), air supply fans running, minimum furnace temperature, and flame safety systems in normal operational status.)
- NCG flow not too low at the incineration point.
- NCG temperature not too high at the incineration point.
- HVLC NCG temperature not too low at the boiler.
- NCG pressure not too high anywhere in the system.
- Foul condensate level not too high in condensate drains and/or condensate collection tank(s) anywhere near the incineration point.
- HVLC NCG blower(s) running.
- LVHC NCG steam ejector operation normal (normal steam flow and steam pressure to the ejector).

The venting of gases from the incineration point may, under certain conditions, be followed by transfer of NCG to a secondary or back-up incineration point. This provision will minimise the total amount of NCG system venting.

Summary

The options available for the incineration of NCGs include a power boiler, a dedicated waste gas incinerator, a lime kiln (for LVHC NCG and smaller HVLC NCG systems only), a recovery boiler, and a regenerative thermal oxidizer (for HVLC NCG systems only). The comparison of the various options for NCG incineration should take into account a number of site-specific considerations, which include the following:

- The volume of the NCG to be incinerated.
- The air flow requirements, relative to the NCG flow, for the incineration point under consideration.
- The regulatory permitting requirements for the incineration point under consideration.
- The existence of stack monitoring equipment for SO2 and/or TRS on the incineration point under consideration.
- The existence of flue gas scrubbing equipment for SO2 on the incineration point under consideration.
- The cost of oil or natural gas to be used as either primary or auxiliary fuel for a dedicated waste gas incineration system.
- The availability of high-Btu-value waste gas (especially SOG) to provide the primary fuel for a dedicated waste gas incinerator.
- The physical proximity of the various candidate incineration points to the majority of the NCG sources.
- The availability of a suitable location for the injection of NCG gases into the incineration point under consideration.
- Past experience with the incineration of waste gases in one or more of the candidate incineration points.

- The operational availability factor for each of the candidate incineration points.
- The potential for corrosion in existing air systems and/or leakage of malodorous and noxious gases to the surrounding mill environment.
- The presence of turpentine vapors in the NCG.

When the appropriate safety and operational considerations are applied to the design of the ff¥iP6 system, these gases can be treated safely and effectively with any of several incineration equipment options at any kraft pulp mill. However, the capital and operating costs for the different options will vary greatly from one mill to another, depending upon the site-specific considerations listed above.

The following table summarizes the typical suitability of various incineration equipment alternatives for waste gases. A "+" or a "—" beneath each incineration equipment alternative indicates its relative suitability for the type of waste gas or gases listed.

Types Of Incineration Equipment

TYPE(S) OF WASTE GAS	POWER BOILER	INCINERATOR	RECOVERY BOILER	LIME KILN	RTO
LVHC	+	+	+	+	-
SOG	4-	+	+	+	-
Low HVLC	+	+	+	+	+
High HVLC	+	-	+	-	+
Low HVLC & LVHC	+	+	+	+	-
Low HVLC, LVHC, & SOG	+	+	+	+	-
Low HVLC & SOG	+	+	+	+	-
LVHC & SOG	+	+	+	+	-
High HVLC & LVHC	+	-	+	-	+
High HVLC, LVHC, & SOG	+	-	+	-	-
High HVLC & SOG	+	-	+	-	-